XIII. *Defcription of a Lamp-Micrometer, and the Method of ufing it. By Mr.* William Herfchel, *F. R. S.*

Read January 31, 1782.

THE great difficulty of meafuring very fmall angles, fuch as hardly amount to a few feconds, is well known to aftronomers. Since I have been engaged in obfervations on double ftars, I have had fo much occafion for micrometers that would meafure exceeding fmall diftances exactly, that I have continually been endeavouring to improve thefe inftruments.

The natural imperfections of the parallel wire micrometer in taking the diftance of very clofe double ftars are the following. When two ftars are taken between the parallels, the diameters muft be included. I have in vain attempted to find lines fufficiently thin to extend them acrofs the centers of the ftars fo that their thicknefs might be neglected. The fingle threads of the filk-worm, with fuch lenfes as I ufe, are fo much magnified that their diameter is more than that of many of the ftars. Befides, if they were much lefs than they are, the power of deflection of light would make the attempt to meafure the diftance of the centers this way fruitlefs: for I have always found the light of the ftars to play upon thofe lines and feparate their apparent diameters into two parts. Now fince the fpurious diameters of the ftars thus included, to my certain knowledge, are continually changing according to the ftate of the air, and the length of time we look at them, we are, in

ſome reſpect, left at an uncertainty, and our meaſures taken at different times, and with different degrees of attention, will vary on that account. Nor can we come at the true diſtance of the centers of any two ſtars, one from another, unleſs we could tell what to allow for the ſemi-diameters of the ſtars themſelves; for different ſtars have different apparent diameters, which, with a power of 227, may differ from each other (as I have experienced) as far as two ſeconds.

The next imperfection is that which ariſes from a deflection of light upon the wires when they approach very near to each other; for if this be owing to a power of repulſion lodged at the ſurface, it is eaſy to underſtand, that ſuch powers muſt interfere with each other, and give the meaſures larger in proportion than they would have been if the repulſive power of one wire had not been oppoſed by a contrary power of the other wire.

Another very conſiderable imperfection of theſe micrometers is a continual uncertainty of the real zero. I have found, that the leaſt alteration in the ſituation and quantity of light will affect the zero, and that a change in the poſition of the wires, when the light and other circumſtances remain unaltered, will alſo produce a difference. To obviate this difficulty, whenever I took a meaſure that required the utmoſt accuracy, my zero was always taken immediately after, while the apparatus remained in the ſame ſituation it was in when the meaſure was taken; but this enhances the difficulty becauſe it introduces an additional obſervation.

The next imperfection, which is none of the ſmalleſt, is that every micrometer that has hitherto been in uſe requires either a ſcrew or a divided bar and pinion to meaſure the diſtance of the wires or divided image. Thoſe who are acquainted

quainted with works of this kind are but too ſenſible how difficult it is to have ſcrews that ſhall be perfectly equal in every thread or revolution of each thread; or pinions and bars that ſhall be ſo evenly divided as perfectly to be depended upon in every leaf and tooth to perhaps the two, three, or four thouſandth part of an inch; and yet, on account of the ſmall ſcale of thoſe micrometers, theſe quantities are of the greateſt conſequence; an error of a ſingle thouſandth part inducing in moſt inſtruments a miſtake of ſeveral ſeconds.

The laſt and greateſt imperfection of all is, that theſe wire micrometers require a pretty ſtrong light in the field of view: and when I had double ſtars to meaſure, one of which was very obſcure, I was obliged to be content with leſs light than is neceſſary to make the wires perfectly diſtinct; and ſeveral ſtars on this account could not be meaſured at all, though otherwiſe not too cloſe for the micrometer.

The inſtrument I am going to deſcribe, which I call a Lamp-Micrometer, is free from all theſe defects, and has, moreover, to recommend it, the advantage of a very enlarged ſcale. The conſtruction of it is as follows.

ABGCFE (fig. 1) is a ſtand nine feet high, upon which a ſemi-circular board *qhogp* is moveable upwards or downwards, in the manner of ſome fire-ſcreens, as occaſion may require, and is held in its ſituation by a peg *p* put into any one of the holes of the upright piece AB. This board is a ſegment of a circle of fourteen inches radius, and is about three inches broader than a ſemi-circle, to give room for the handles *r*D, *e*P, to work. The uſe of this board is to carry an arm L, thirty inches long, which is made to move upon a pivot at the center of the circle, by means of a ſtring, which paſſes in a groove upon the edge of the ſemi-circle *pgohq*; the ſtring is faſtened

to a hook at *o* (not expreffed in the figure being at the back of the arm L), and paffing along the groove from *ob* to *q* is turned over a pulley at *q*, and goes down to a fmall barrel *e*, within the plane of the circular board, where a double-jointed handle *e*P commands its motion. By this contrivance we fee the arm L may be lifted up to any altitude from the horizontal pofition to the perpendicular, or be fuffered to defcend by its own weight below the horizontal to the reverfe perpendicular fituation. The weight of the handle P is fufficient to keep the arm in any given pofition; but if the motion fhould be too eafy, a friction fpring applied to the barrel will moderate it at pleafure.

In front of the arm L a fmall flider, about three inches long, is moveable in a rabbet from the end L towards the center backwards and forwards. A ftring is faftened to the left fide of the little flider, and goes towards L, where it paffes round a pulley at *m*, and returns under the arm from *m*, *n*, towards the center, where it is led in a groove on the edge of the arm, which is of a circular form, upwards to a barrel (raifed above the plane of the circular board) at *r*, to which the handle *r*D is faftened. A fecond ftring is faftened to the flider, at the right fide, and goes towards the center, where it paffes over a pulley *n*, and the weight *w*, which is fufpended by the end of this ftring, returns the flider towards the center when a contrary turn of the handle permits it to act.

a and *b* are two fmall lamps, two inches high, $1\frac{1}{2}$ in breadth by $1\frac{1}{4}$ in depth. The fides, back, and top, are made fo as to permit no light to be feen, and the front confifts of a thin brafs fliding door. The flame in the lamp *a* is placed three-tenths of an inch from the left fide, three-tenths from the front, and half an inch from the bottom. In the lamp *b* it is placed at the

the ſame height and diſtance meaſuring from the right ſide. The wick of the flame conſiſts only of a ſingle very thin lamp-cotton thread; for the ſmalleſt flame being ſufficient it is eaſier to keep it burning in ſo confined a place. In the top of each lamp muſt be a little ſlit, lengthways, and alſo a ſmall opening in one ſide near the upper part, to permit air enough to circulate to feed the flame. To prevent every reflection of light, the ſide opening of the lamp *a* ſhould be to the right, and that of the lamp *b* to the left. In the ſliding door of each lamp is made a ſmall hole with the point of a very fine needle juſt oppoſite the place where the wicks are burning, ſo that when the ſliders are ſhut down, and every thing dark, nothing ſhall be ſeen but two fine lucid points of the ſize of two ſtars of the third or fourth magnitude. The lamp *a* is placed ſo that its lucid point may be in the center of the circular board where it remains fixed. The lamp *b* is hung to the little ſlider which moves in the rabbet of the arm, ſo that its lucid point, in a horizontal poſition of the arm, may be on a level with the lucid point in the center. The moveable lamp is ſuſpended upon a piece of braſs faſtened to the ſlider by a pin exactly behind the flame upon which it moves as a pivot. The lamp is balanced at the bottom by a leaden weight, ſo as always to remain upright, when the arm is either lifted above, or depreſſed below, the horizontal poſition. The double-jointed handles *r*D, *e*P, conſiſt of light deal rods, ten feet long, and the loweſt of them may have diviſions, marked upon it near the end P, expreſſing exactly the diſtance from the central lucid point in feet, inches, and tenths.

From this conſtruction we ſee, that a perſon at a diſtance of ten feet may govern the two lucid points, ſo as to bring them into any required poſition ſouth or north preceding or following,

from 0 to 90° by ufing the handle P, and alfo to any diftance from fix-tenths of an inch to five or fix and twenty inches by means of the handle D. If any reflection or appearance of light fhould be left from the top or fides of the lamps, a temporary fcreen, confifting of a long piece of pafte-board, or a wire frame covered with black cloth, of the length of the whole arm and of any required breadth, with a flit of half an inch broad in the middle, may be affixed to the arm by four bent wires projecting an inch or two before the lamps, fituated fo that the moveable lucid point may pafs along the opening left for that purpofe.

Fig. 2. reprefents part of the arm L, half the real fize; S the flider; *m* the pulley, over which the cord *xtyz* is returned towards the center; *v* the other cord going to the pulley *n* of fig. 1. R the brafs piece moveable upon the pin *c*, to keep the lamp upright. At R is a wire rivetted to the brafs piece, upon which is held the lamp by a nut and fcrew. Fig. 3. 4. reprefent the lamps *a*, *b*, with the fliding doors open, to fhew the fituation of the wicks. W is the leaden weight with a hole *d* in it, through which the wire R of fig. 2. is to be paffed when the lamp is to be faftened to the flider S. Fig. 5. reprefents the lamp *a* with the fliding door fhut; *l* the lucid point; and *ik* the openings at the top, and *s* at the fides for the admiffion of air.

Every ingenious artift will foon perceive that the motions of this micrometer are capable of great improvement by the application of wheels and pinions, and other well known mechanical refources; but, as the principal object is only to be able to adjuft the two lucid points to the required pofition and diftance, and to keep them there for a few minutes, while the obferver

obſerver goes to meaſure their diſtance, it will not be neceſſary to ſay more upon the ſubject.

I am now to ſhew the application of this inſtrument. It is well known to opticians and others, who have been in the habit of uſing optical inſtruments, that we can with one eye look into a microſcope or teleſcope, and ſee an object much magnified, while the naked eye may ſee a ſcale upon which the magnified picture is thrown. In this manner I have generally determined the power of my teleſcopes; and any one who has acquired a facility of taking ſuch obſervations will very ſeldom miſtake ſo much as one in fifty in determining the power of an inſtrument, and that degree of exactneſs is fully ſufficient for the purpoſe.

The Newtonian form is admirably adapted to the uſe of this micrometer; for the obſerver ſtands always erect, and looks in a horizontal direction, notwithſtanding the teleſcope ſhould be elevated to the zenith. Beſides, his face being turned away from the object to which his teleſcope is directed, this micrometer may be placed very conveniently without cauſing the leaſt obſtruction to the view: therefore, when I uſe this inſtrument I put it at ten feet diſtance from the left eye, in a line perpendicular to the tube of the teleſcope, and raiſe the moveable board to ſuch a height that the lucid point of the central lamp may be upon a level with the eye. The handles, lifted up, are paſſed through two loops faſtened to the tube, juſt by the obſerver, ſo as to be ready for his uſe. I ſhould obſerve, that the end of the tube is cut away ſo as to leave the left eye intirely free to ſee the whole micrometer.

Having now directed the teleſcope to a double ſtar, I view it with the right eye, and at the ſame time with the left ſee it pro-

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jected upon the micrometer: then, by the handle P, which commands the poſition of the arm, I raiſe or depreſs it ſo as to bring the two lucid points to a ſimilar ſituation with the two ſtars; and, by the handle D, I approach or remove the moveable lucid point to the ſame diſtance of the two ſtars, ſo that the two lucid points may be exactly covered by, or coincide with the ſtars. A little practice in this buſineſs ſoon makes it eaſy, eſpecially to one who has already been uſed to look with both eyes open.

What remains to be done is very ſimple. With a proper rule, divided into inches and fortieth parts, I take the diſtance of the lucid points, which may be done to the greateſt nicety, becauſe, as I obſerved before, the little holes are made with the point of a very fine needle. The meaſure thus obtained is the tangent of the magnified angle under which the ſtars are ſeen to a radius of ten feet; therefore, the angle being found and divided by the power of the teleſcope gives the real angular diſtance of the centers of a double ſtar.

For inſtance, September 25, 1781, I meaſured α Herculis with this inſtrument. Having cauſed the two lucid points to coincide exactly with the ſtars center upon center, I found the radius or diſtance of the central lamp from the eye 10 feet 4,15 inches; the tangent or diſtance of the two lucid points 50,6 fortieth parts of an inch; this gives the magnified angle $35'$, and dividing by the power 460, which I uſed, we obtain $4''\ 34''$ for the diſtance of the centers of the two ſtars. The ſcale of the micrometer at this very convenient diſtance, with the power of 460 (which my teleſcope bears ſo well upon the fixed ſtars that for near a twelve-month paſt I have hardly uſed any other) is above a quarter of an inch to a ſecond; and by putting on my power of 932, which in very fine evenings is

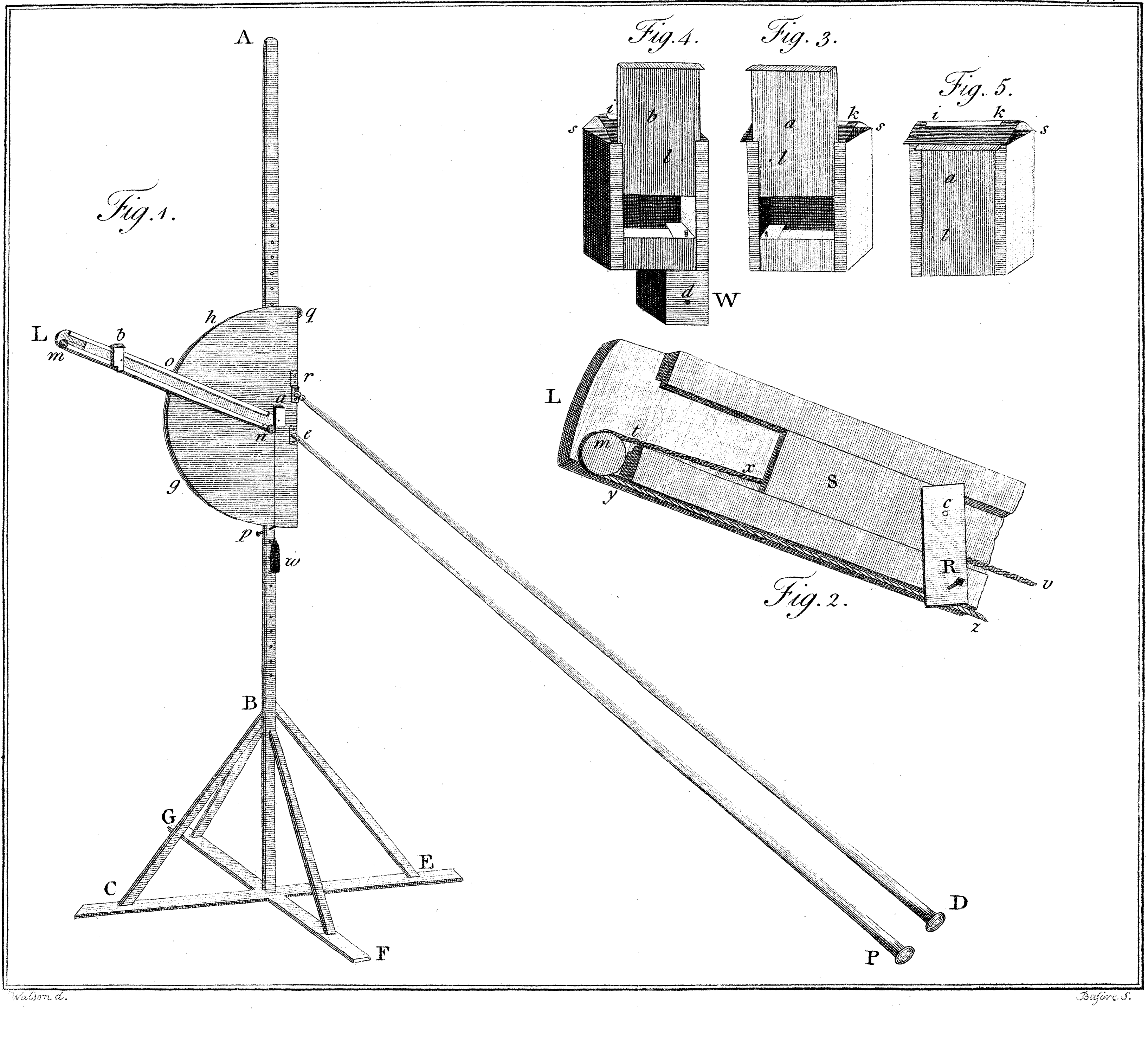
extremely diſtinct, I obtain a ſcale of more than half an inch to a ſecond, without increaſing the diſtance of the micrometer; whereas the moſt perfect of my former micrometers, with the ſame inſtrument, had a ſcale of leſs than the two thouſandth part of an inch to a ſecond.

The meaſures of this micrometer are not confined to double ſtars only, but may be applied to any other objects that require the utmoſt accuracy, ſuch as the diameters of the planets or their ſatellites, the mountains of the moon, the diameters of the fixed ſtars, &c.

For inſtance, October 22, 1781, I meaſured the apparent diameter of α Lyræ; and judging it of the greateſt importance to increaſe my ſcale as much as convenient, I placed the micrometer at the greateſt convenient diſtance, and (with ſome trouble, for want of longer handles, which might eaſily be added) took the diameter of this ſtar by removing the two lucid points to ſuch a diſtance as juſt to incloſe the apparent diameter. When I meaſured my radius it was found to be twenty-two feet ſix inches. The diſtance of the two lucid points was *about* three inches; for I will not pretend to *extreme* nicety in this obſervation, on account of the very great power I uſed, which was 6450. From theſe meaſures we have the magnified angle $38' \, 10''$: this divided by the power gives $0'',355$ for the apparent diameter of α Lyræ. The ſcale of the micrometer, on this occaſion, was no leſs than 8,443 inches to a ſecond, as will be found by multiplying the natural tangent of a ſecond with the power and radius in inches.

November 28, 1781, I meaſured the diameter of the new ſtar; but the air was not very favourable, for this ſingular ſtar was not ſo diſtinct with 227 that evening as it generally is

with 460: therefore, without laying much ſtreſs upon the exactneſs of the obſervation, I ſhall only report it to exemplify the uſe of the micrometer. My radius was 35 feet 11 inches. The diameter of the ſtar, by the diſtance of the lucid points, was 2,4 inches, and the power I uſed 227: hence the magnified angle is found 19′, and the real diameter of the ſtar 5″,022. The ſcale of this meaſure ,474 milleſimals of an inch, or almoſt half an inch to a ſecond.



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